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Effect of seed priming on yield and economics of rainfed maize-pea sequence under mid hill conditions of Himachal Pradesh

Munish Sharma and DK Parmar

Abstract
A study was carried out for two years (2014-15 and 2015-16) at the experimental farm of Hill Agricultural Research and Extension Centre, Bajaura, Kullu (31°84´ N latitude and 77°16´ E longitude). Four priming levels of Zn (0% $ZnSO_4$-water soaking, 1% $ZnSO_4$, 2% $ZnSO_4$ and 3% $ZnSO_4$) and three priming durations (4 hours, 8 hours and 12 hours) were compared with basal dose of recommended NPK + $ZnSO_4$ and farmers' practice (absolute control). The yield of green peas, maize equivalent, stover yield, net returns and B:C were maximum due to priming with 1% $ZnSO_4$ for 12 hours duration, however, maize grain, stover yield, net returns and B:C were highest with treatment combination of 2% $ZnSO_4$ priming for 12 hours duration. In nutshell, it may be concluded that priming of pea seeds for 12 hours with 1% $ZnSO_4$ and that of maize seeds for 12 hours using 2% solution of $ZnSO_4$ may be useful for yield, net returns and B:C ratio.

Keywords: Seed priming, maize-pea sequence, yield, economics

Introduction
Seed priming is an effective technology to enhance rapid and uniform germination, emergence of seeds and to increase seed tolerance to adverse environmental conditions. It is a controlled hydration process followed by re-drying that allows seed to imbibe water and begin internal biological processes necessary for germination, but not allow the seed to germinate (Kathiresan *et al*. 1984) [21]. Seed priming improves the germination rate, speed and uniformity even under less than optimal field conditions, thus enabling the establishment of uniform and good crop stand establishment (Kant *et al*. 2006) [19]. It has been found to be a double technology to enhance rapid and uniform emergence and to achieve high vigour and better yields in many crop species (Farooq *et al*. 2007) [9]. Likewise in another study, seed treatment with Zn in rice crop substantially improved growth and grain yield, which was cost effective and economically more viable than soil application and no application (Slaton *et al*. 2001) [35].
Maize-garden pea is most important cropping system under rain-fed conditions, being adopted by the farmers in Himachal Pradesh. However, significant yield losses in maize and pea are expected to increase with global climate change in key production areas. Water scarcity is major constraint which is beyond the control of farmers. Hence, increasing water use efficiency for enhanced drought tolerance can be achieved by involving agronomic practices like seed priming (Harris *et al*. 2005) [11]. Hence, in the present investigation, effect of seed priming on yield and economics of rainfed maize-pea sequence under mid hill conditions of Himachal Pradesh was undertaken.

Material and Methods
Experimental site
The experimental site was Research Farm of Hill Agricultural Research and Extension Centre, Bajaura, Kullu (31°84´ N latitude and 77°16´ E longitude), which is located at an altitude of 1090 m above mean sea level.

Climate
Agro-climatically, the study location represents zone II of Himachal Pradesh and is characterized by hot dry summers, sub humid rainy season and cool winters. The region receives an average rainfall of 873 mm per annum and major portion of rainfall (about 55%) is received during winter and dry spell are common from October to December.

Soil characteristics

The soil of the experimental site at initiation of the experiment was slightly acidic in reaction, medium in organic carbon, silty loam in texture, medium in available nitrogen and potassium and high in phosphorus and DTPA-extractable Fe, Mn, Zn and Cu. Some important initial physico-chemical characteristics of the experimental site (0-0.15 m) are provided in Table 1.

Experimental details

Field trials were conducted for two years during 2014-5 and 2015-16 taking maize and pea in a sequence. The experiment consisted of four priming levels (0 % $ZnSO_4$ -water soaking, 1% $ZnSO_4$, 2% $ZnSO_4$ and 3% $ZnSO_4$) and three priming durations (4 hr, 8 hr and 12 hr), which were compared with Recommended basal NPK + $ZnSO_4$ and farmers' practice (40% N of RDF + unprimed seed – control). The treatments were replicated thrice in a factorial RBD.

Seed Priming

Four priming levels of $ZnSO_4$ namely 0 % (water soaking), 1%, 2.0% and 3%) used. The solutions of Zinc Sulfate were prepared by dissolving 10, 20 and 30 g of $ZnSO_4$ (21% Zn) per litre of distilled water to make 1%, 2.0% and 3% solution. Approximately 30 g seeds of maize and 170 g that of pea were soaked in one litre of water for 4, 8 and 12 hours. Similarly the above mentioned quantity of seeds was soaked in distilled water separately for 4, 8 and 12 hours. After soaking, the seeds were dried in shade until seed coat become dry.

Fertilizers

All the plots received recommended dose of N: P: K fertilizers and FYM (25:60:60 kg ha^{-1} + 10 t ha^{-1} for pea and 120:60:40 kg ha^{-1} + 10 t ha^{-1} for maize). The source of N, P and K fertilizer was urea, single super phosphate and muriate of potash, respectively. The whole quantity of P and K fertilizers along with FYM and half dose of N were applied at the time of maize sowing and remaining N was top dressed as two equal splits. In pea crop, whole quantity of fertilizers and FYM was applied at the time of sowing.

Result and Discussion

Green pea pods, maize grains and maize equivalent yield

Effect of priming level

The data pertaining to the effect of different priming levels on fresh green pods yield of pea has been highlighted in table 2. It is clear from the data that there was a remarkable influence of different priming levels on green pods yield of pea. The priming with 1% $ZnSO_4$ gave maximum yield followed by 0% $ZnSO_4$ (water soaking), but yield further declined with increasing priming concentration of $ZnSO_4$ from 2% to 3%. The priming with 1% $ZnSO_4$, as compared to 0% $ZnSO_4$ (water soaking), 2% $ZnSO_4$ and 3% $ZnSO_4$ increased green pods yield by 6.3, 14.5 and 86.3%, respectively during 2014-15; 6.3, 14.5 and 84.3%, respectively in 2015-16 and 6.3, 14.6 and 85.3%, respectively for the pooled yield.

The data pertaining to the effect of priming levels on maize grain yield has been provided in table 2. The data revealed that different priming levels significantly influenced grain yield of maize and the maximum increase was recorded for priming with 2% $ZnSO_4$ followed by 1% $ZnSO_4$ and 0% $ZnSO_4$(water soaking), whereas, minimum yield was recorded with 3% $ZnSO_4$ priming solution. Priming with 2% $ZnSO_4$ increased yield as compared to priming with 0% $ZnSO_4$ (water soaking), 1% $ZnSO_4$ and 3% $ZnSO_4$ by 29.6, 12.1 and 67.1%, respectively in the year 2015; 29.9, 12.3 and 69.0%, respectively in 2016 and 29.9, 12.3 and 67.8%, respectively for pooled yield.

The priming levels exerted a significant effect on maize equivalent yield during both years and pooled yield (Table 2). The priming with 1% $ZnSO_4$ recorded highest maize equivalent yield of 238.0 q ha^{-1} in 2015, 244.2 q ha^{-1} during 2016 and 241.4 q ha^{-1} on pooling the data. The minimum maize equivalent yield was observed due to priming with 3% $ZnSO_4$ solution which was 134.1 q ha^{-1} in 2015, 138.6 q ha^{-1} in 2016 and 136.4 q ha^{-1} for pooled data. The maize equivalent yield obtained under 2% $ZnSO_4$ and 0 % $ZnSO_4$ (water soaking) was statistically equal during both years and on pooling the data.

Effect of priming duration

The data showing the effect of varying priming durations on green pods yield of pea has been presented in table 2. The data indicated that yield of pea pods differ significantly among priming durations. The pods yield increased with increasing duration time from 4 to 12 hours and the highest yield was obtained for 12 hours, which increased yield over 8 and 4 hours duration by 6.8 and 18.7%, respectively in the year 2014-15; 6.5 and 18.1%, respectively during 2015-16 and 6.6 and 18.3%, respectively in case of pooled data.

The maize grain yield has been presented in table 2 and the data revealed that yield observed significant differences among duration treatments and the maximum yield was recorded for 12 hours duration time, which increased yield over 8 and 4 hours duration by 16.4 and 38.6%, respectively in 2015; 15.7 and 37.3%, respectively in 2016 and 16.2 and 38.2%, respectively in case of pooled data.

The maize equivalent yield differ significantly among varying priming durations from 4 to 12 hours (Table 2). The yield increased with increasing priming durations and highest maize equivalent yield was obtained for 12 hours priming duration (222.7 q ha^{-1}in 2015, 228.4 q ha^{-1}during 2016 and 225.6 q ha^{-1}pooled yield), followed by 8 hours priming (204.8 q ha^{-1} during 2015, 210.4 q ha^{-1} in 2016 and 207.6 q ha^{-1} on pooling data) and 4 hours priming duration (181.6 q ha^{-1}during 2015, 187.1 q ha^{-1} during 2016 and 184.3 q ha^{-1} in case of pooled yield).

Interaction effect

The green pod yield of pea during individual year and for pooled data was significantly influenced due to interaction among priming levels and their duration (Table 2). On the basis of observed interaction, it was noticed that maximum green pod yield of 136.2 q ha^{-1} in 2014-15; 139.3 q ha^{-1} in 2015-16 and 137.8 q ha^{-1} in case of pooled yield, was recorded due to priming with 1% $ZnSO_4$ for 12 hours duration.

The data in table 2 further revealed that interaction among priming levels and their duration was positive and significant for maize grain yield during both years and pooled data. The maximum grain yield of 69.2 q ha^{-1} in 2015; 71.0 q ha^{-1} in 2016 and 70.1 q ha^{-1} was recorded with 2% $ZnSO_4$ solution for 12 hours duration.

The interaction among treatments was also found significant with respect to maize equivalent yield during both years as well as on pooling the data and highest yield was obtained with a treatment combination of 1% $ZnSO_4$ priming for 12 hours duration (Table 2).

Priming vs Basal $ZnSO_4$

The data presented in table 2 revealed that yield of fresh pea pods observed significant differences among priming and soil application of $ZnSO_4$. The observed increase in pod yield due to priming over soil applied $ZnSO_4$ was 15.6% in 2014-15; 15.3% in 2015-16 and 15.4% for pooled data.

A perusal of data in table 2 indicated that there was a significant effect of priming over soil application of $ZnSO_4$ during individual year and on pooling of the data. The priming treatments increased maize grain yield over soil applied $ZnSO_4$ by 21.9% in 2015; 20.5% in 2016 and 21.3% for pooled data.

The data in table 2 further showed that maize equivalent yield differ significantly among priming and soil applied Zn during both years and pooled data. The priming treatments recorded higher equivalent yield (203.0 qha^{-1} in 2015; 208.6 q ha^{-1} and 205.8 q ha^{-1} for pooled data) in comparison to soil application of $ZnSO_4$ (173.7 qha^{-1} in 2015; 179.2 q ha^{-1} and 176.4 q ha^{-1} for pooled data).

Control vs others

The data presented in table 2 demonstrated that pod yield of pea differ among treatments and control. The treatments increased yield over control by 19.5% in 2014-15; 19.2% in 2015-16 and 19.3% for pooled data.

The data in table 2 revealed that treatments had significantly better maize grain yield than control during individual year and on pooling of the data and the treatments increased maize grain yield over control by 26.6% in 2015; 24.9% in 2016 and 25.4% for pooled data.

The data provided in table 2 further showed that other treatments had significantly higher maize equivalent yield during both years and pooled yield and treatments recorded maximum maize equivalent yield of 200.8 q ha^{-1} in 2015; 206.4 q ha^{-1} in 2016 and 203.6 q ha^{-1} for pooled data in comparison to control 166.1 q ha^{-1} in 2015; 171.4 q ha^{-1} in 2016 and 168.8 q ha^{-1} for pooled data.

The higher yield obtained during the current investigation can be explained on the grounds that seed priming with micronutrients increased seed yield and this increase can be related to rapid, optimal establishment of the plants and their greater ability in using nutrient. The primed seed emerge fast and more uniform and seedling grown more vigorously, leading to a wide range of phonological and yield related benefits. Therefore, better use of nutritional resources due to early emergence of plants can eventually result in higher seed yield of cereal crops (Badiri *et al*. 2014) [5].

Higher yield of pea and maize due to Zn priming is attributed to the enhanced synthesis of carbohydrates and their transport to the site of grain production (Pedda-Babu *et al*. 2007) [30]. Similar results were also reported by various researchers due to Zinc seed priming on grain yield of wheat (Nazir *et al*. 2000; Harris *et al*. 2005; Aboutalebian *et al*. 2012) [29, 11, 1], chickpea (Arif *et al*. 2007) [7, 13], maize (Harris *et al*. 2007; Imran *et al*. 2013; Mohsin *et al*. 2014) [13, 17, 16, 27], barley (Rashid *et al*. 2006) [33], rice (Harris *et al*. 1999) [28], sunflower (Kahlon *et al*. 1992; Hussain *et al*. 2006) [18, 15] and pea (Golezani *et al*. 2008). Nutrient priming has been shown to improve crop stand establishment, which can reportedly improve drought tolerance, reduce pest damage, increase crop yield (Harris *et al*. 1999; Mussa *et al*. 1999; Harris *et al*. 2000) [28, 32].

Considering the concentration of $ZnSO_4$ used in this study, it is expected that the higher Zn concentration used was completely absorbed by the seeds, this level probably exerted toxic effects, thereby reducing their performance due to interruption of cell division and development Reid *et al*. (2004) [34]. Working with barley, Karabal *et al*. (2003) [20] observed that exposure of barley seedlings to B solutions at higher concentrations caused damage to membranes, thereby increasing membrane permeability and the malondialdehyde content of the cell, which is an important marker of oxidative stress.

Johansen *et al*. (2007) [17] reported significantly higher grain yield under the molybdenum loading treatments than 0 % $ZnSO_4$ (water soaking). Arif *et al*. (2007) [7, 13] recorded higher yield of chickpea and wheat Similarly, Khanal *et al*. (2004-05) [24] recorded higher mungbean yield under sodium molybdate loading than 0 % $ZnSO_4$ (water soaking). 0 % $ZnSO_4$ (water soaking) (8 hour) of mungbean seed produced higher grain yield than control (Rashid *et al*. 2004) [31]. Maskey *et al*. (2007) [25] reported chickpea and phaseolus bean yield increased with boron and molybdenum application. Umair *et al*. (2011) [37] found similar effect on seed yield of mungbean under dry seed, hydro-priming and molybdenum loading treatments. Increased sucrose synthase and glutamine synthetase activities in primed chickpeas nodule enhanced nodule biomass, metabolic activity, seed fill and better yield (Kaur *et al*. 2006; Khan *et al*. 2008; Subedi and Yadav 2013) [22, 23, 36].

Stover yield of pea and maize

Effect of priming level

A cursory look into the data presented in table 3 indicated that stover yield of pea was significantly influenced among different priming levels and maximum yield was recorded with 1% $ZnSO_4$ priming, which increased stover yield of pea $ZnSO_4$ in comparison to 0% $ZnSO_4$ (water soaking), 2% $ZnSO_4$ and 3% $ZnSO_4$ by 11.6, 26.1 and 119.1%, respectively during 2014-15; 11.7, 26.5 and 118.1%, respectively in 2015-16 and 11.6, 26.3 and 118.6%, respectively for pooled data.

Further the data presented in table 3 indicated that maize stover yield significantly varied among priming levels and the maximum stover yield was recorded for priming with 2% $ZnSO_4$ and it increased stover yield in comparison to 0% $ZnSO_4$ (water soaking), 1% $ZnSO_4$ and 3% $ZnSO_4$ priming solution by 33.5, 14.0 and 88.3%, respectively in 2015; 34.1, 14.5 and 89.3%, respectively in 2016 and 33.9, 14.2 and 88.8%, respectively for the pooled data.

Effect of priming duration

The data in relation to pea stover yield as influenced by different priming durations have been given in table 3. The results showed that pea stover yield varied significantly among different priming durations and maximum yield was recorded for 12 hours priming duration, which increased yield in comparison to 8 and 4 hours priming duration by 6.9 and 18.6%, respectively in the year in 2014-15; 6.6 and 18.0%, respectively during 2015-16 and 7.2 and 18.5%, respectively for 8 and 4 hours duration in case of pooled data.

The data with respect to the effect of different priming durations on maize stover yield is presented in table 3. The data suggests that maize stover yield was significantly different among priming durations and the maximum stover yield was recorded for 12 hours duration, which increased stover yield over priming duration of 8 and 4 hours by 17.1 and 43.6%, respectively in the year in 2015; 16.5 and 42.1%, respectively during 2016 and 16.8 and 42.7%, respectively in case of pooled data.

Interaction Effect

the stover yield of pea was significantly influenced due to interaction among priming levels and their duration (Table 3). It was observed that priming with 1% $ZnSO_4$ for 12 hours duration recorded maximum pea stover yield of 34.1 q ha^{-1} in 2014-15; 35.7 q ha^{-1} in 2015-16 and 34.9 q ha^{-1} for pooled yield.

The interaction among priming levels and their duration was also found significant for maize stover yield and on the basis of observed interaction, it can be infer that priming with 2% $ZnSO_4$ for 12 hours duration recorded maximum stover yield of 121.8 q ha^{-1} in 2015; 125.3 q ha^{-1} in 2016 and 123.6 q ha^{-1} for pooled data. (Table 3)

Priming vs Basal $ZnSO_4$

An examination of data presented in table 3 indicated that priming exhibited a significant effect on pea stover yield than soil application of $ZnSO_4$, and priming increased stover yield in comparison to soil applied $ZnSO_4$ by 22.1% in 2014-15; 22.0% in 2015-16 and 22.1% for pooled data.

An examination of data presented in table 3 showed that the effect of priming was found to be significantly superior to soil application of $ZnSO_4$ and priming treatments increased maize stover yield over Zn application in soil by 22.8% in 2015; 21.9% in 2016 and 22.3% for pooled data.

Control vs others

The priming treatments produced higher stover yield than control and treated plots observed an increase in yield over control to the tune of 24.4% in 2014-15, 23.5% in 2015-16 and 23.6% for pooled data (Table 3).

The data presented in table 3 further demonstrated that treatments significantly influenced maize stover yield in comparison to control and maize stover yield due to treatments was highest as much as 28.1% in 2015; 26.9% in 2016 and 27.4% for pooled data.

Zinc plays critical role in crop growth, involving in photosynthesis processes, respiration and other biochemical and physiological activates and thus their importance in achieving higher yields (Zeidan *et al*. 2010) [38]. These results endorse the finding of Rashid *et al*. (2000) [32], who reported that priming treatment significantly increased total biomass and dry weight as compared to control. Higher straw yield due to seed priming with Zinc enhanced the photosynthesis process and translocation of the photosynthesis, which resulted in enhanced enzymatic activity and other biological activity. The results are in close agreement with Chhibba *et al*. (2007) [8] and Meena *et al*. (2013) [26], who observed increased rice straw yield for priming as compared to no soaking. In barley seed priming with zinc caused marked increase in accumulation of dry matter in barley Arif *et al*. (2007) [7, 13] also reported that seed priming in Zinc solution had pronounced effect on dry matter yield of wheat and chickpea.

The increase in biological yield might be due to better early seedling growth and plant nutrition as report by Zhang *et al*. (2009) [39]. These results also coincide with the finding of Badiri *et al*. (2014) [5], who reported that total biomass significantly increased due to seed priming with Zn, Fe, Mn. also observed that priming methods and time increased biological yield of soybean. Stated that in Zn-deficient soils, plants of Zn-rich seeds produced higher dry matter and absorbed Zn with higher efficiencies at the later growth stages. Arif *et al*. (2007) [7, 13] also reported that seed priming in Zinc solution significantly affected biological yield of wheat and chickpea. According to them, the increase in biological yield might be due to better early seedling growth and plant nutrition as report by Zhang *et al*. (2009) [39].

Net returns and B:C of pea and maize crop

Effect of priming level

The data in table 4 and 5 revealed that different priming levels significantly increased net monetary returns and B:C of pea crop. The maximum net returns and B:C were obtained for priming with 1% $ZnSO_4$ (rupees 1 91 113 ha^{-1} and 2.93) as compared to 0% $ZnSO_4$ (water soaking) (rupees 1 75 723 $ha^{-1}$and 2.70 in 2014-15, rupees 1 97 788 $ha^{-1}$and 3.04 in 2015-16 and rupees 1 94 450 ha^{-1} and 2.98 for pooled data), 2% $ZnSO_4$ (rupees 1 57 765 $ha^{-1}$and 2.42 in 2014-15, rupees 1 63 524 $ha^{-1}$and 2.50 in 2015-16 and rupees 1 60 645 $ha^{-1}$and 2.46 for pooled data) and 3% $ZnSO_4$ (rupees 71 313 ha^{-1} and 1.09 in 2014-15, rupees 76 362 ha^{-1} and 1.17 during 2015-16 and rupees 73 837 ha^{-1} and 1.13 in case of pooled data).

The priming levels significantly increased net monetary returns and B:C of maize crop and maximum net returns and B:C were recorded due to priming with 2% $ZnSO_4$ (rupees 57 515 ha^{-1} and 1.54 in the year 2015, rupees 60 740 ha^{-1} and 1.63 and rupees 59 128 ha^{-1} and 1.59 in case of pooled data) followed by 1% $ZnSO_4$ (rupees 47 009 ha^{-1} and 1.27 in 2015, rupees 49 679 ha^{-1} and 1.34 in the year 2016 and rupees 48 344 ha^{-1} and 1.30 related to pooled data), 0% $ZnSO_4$ (water soaking) (rupees 35 501 $ha^{-1}$and 0.96 during 2015, rupees 37 796 ha^{-1} and 1.02 for 2016 and rupees 36 648 $ha^{-1}$and 0.99 with respect to pooled data) and 3% $ZnSO_4$ (rupees 17 611 $ha^{-1}$and 0.47 in 2015, rupees 18 935 $ha^{-1}$and 0.51 in 2016 and rupees 18 273 $ha^{-1}$and 0.49 for pooled data).

Effect of priming duration

The data in table 4 to 5 demonstrated that net monetary returns and B:C of pea crop differ significantly among varying priming durations. The priming duration for 12 hours gave maximum net returns and B:C (rupees 1 65 957 $ha^{-1}$and 2.55 in 2014-15, rupees 1 71 896 ha^{-1} and 2.64 in 2015-16 and rupees 1 68 927 ha^{-1} and 2.59 in case of pooled data) as compared to 8 hours (rupees 1 51 396 ha^{-1} and 2.32 in 2014-15, rupees 1 57 321 ha^{-1} and 2.41 in 2015-16 and rupees 1 54 358 ha^{-1} and 2.37 with respect to pooled data) and 4 hours (rupees 1 29 582 ha^{-1} and 1.99 in 2014-15, rupees 1 35 492 ha^{-1} and 2.08 in 2015-16 and rupees 1 32 537 ha^{-1} and 2.03 in case of pooled data).

The data in table 4 to 5 indicated that different priming durations posed a significant effect on net monetary returns and B:C of maize crop. The maximum net returns and B:C were provided by 12 hours priming (rupees 52 092 ha^{-1} and 1.40 in 2015, rupees 54 548 ha^{-1} and 1.47 in 2016 and rupees 53 320 ha^{-1} and 1.43 for pooled data) followed by 8 hours priming (rupees39 414 ha^{-1} and 1.06 in 2015, rupees 41 852 ha^{-1} and 1.12 in 2016 and rupees 40 633 ha^{-1} and 1.09 in case of pooled data) and 4 hours priming (rupees 26 720 ha^{-1} and 0.72 in 2015, rupees 28 962 ha^{-1} and 0.78 in 2016 and rupees 27 841 ha^{-1} and 0.75 for pooled data).

Interaction effect

The data in table 4 and 5 revealed that during the current study, net returns and B:C of pea and maize were positively and significantly influenced due to interaction among priming levels and their duration. On the basis of observed interaction, it can be infer that highest net returns and B:C of pea crop were obtained due to priming with 1% $ZnSO_4$ for a period of 12 hours (rupees 2 17 465 ha^{-1} and 3.3 in 2014-15, rupees 2

24 165 ha^{-1}and 3.40 during 2015-16 and rupees 2 20 815 ha^{-1} and 3.40 for pooled data). Similarly, interaction among treatments was also found significant in case of net returns and B:C of maize crop during both study years and on pooling the data. The treatment combination of priming with 2% $ZnSO_4$ for a period of 12 hours recorded maximum net returns and B:C to the tune of rupees 84 630 ha^{-1} and 2.3 in 2015, rupees 87 895 ha^{-1}and 2.40 during 2016 and rupees 86 263 ha^{-1} and 2.30 in case of pooled data.

Priming vs Basal $ZnSO_4$

The results of the current study showed that net returns and B:C of pea and maize crop were significantly different among priming levels and application of $ZnSO_4$ in soil (Table 4 to 5). The maximum net returns and B:C of pea crop were obtained with priming treatments (rupees 1 48 978 ha^{-1} and 2.29 in 2014-15,rupees 1 54 903 ha^{-1} and 2.38 in 2015-16 and rupees 1 51 941 ha^{-1} and 2.33 in case of pooled data) as compared to soil application of $ZnSO_4$ (rupees 1 18 467 ha^{-1} and 1.78 in 2014-15, rupees 1 23 980 ha^{-1} and 1.86 in 2015-16 and rupees 1 21 223 ha^{-1} and 1.82 for pooled data). Likewise, the maximum net returns and B:C of maize crop were found with priming treatments (rupees 39 409 ha^{-1} and 1.06 in 2014-15, rupees 41 787 ha^{-1} and 1.12 during 2015-16 and 40 598 ha^{-1} and 1.09 with respect to pooled data) as compared to soil application of $ZnSO_4$ (rupees 25 212 ha^{-1} and 0.67 in 2015, rupees 27 837 ha^{-1} and 0.74 for 2016 and 26 525 ha^{-1} and 0.71 for pooled data).

Control vs others

The data in table 4 to 5 further revealed that treatments had significantly higher net returns and B:C ratio of pea crop as compared to control during both years and on pooling the data. The net returns and B:C obtained from pea crop under treatments were rupees 1 46 631 ha^{-1} and 2.25 in 2014-15, rupees 1 52 524 ha^{-1} and 2.34 during 2015-16 and 1 49 578 ha^{-1} and 2.29 in case of pooled data) as compared to control, where net returns and B:C were rupees 1 18 564 and 2.02 in 2014-15, rupees 1 23 871 and 2.11 in 2015-16 and rupees 1 21 217 and 2.07 for pooled data.

The data in table 4 to 5 further showed that treatments significantly increased net returns and B:C ratio of maize crop in comparison to control during the study. The highest net returns and B:C were found under treatments (rupees 38 317 ha^{-1} and 1.03 in 2015, rupees 40 714 ha^{-1} and 1.09 during 2016 and 39 516 ha^{-1} and 1.06 for pooled data) when compared with control (rupees 27 600 and 0.74 in 2015, rupees 30 217 and 0.80 in 2016 and rupees 28 909 and 0.77 for pooled data).

Benefit cost ratio is the ratio of gross return to cost of cultivation which can also expressed as returns per rupee invested. Any value greater than two is considered safe as the farmer get two every rupee invested. Berchie *et al*. (2010) [6] advocated that seed priming is cheap and easy technology to adopt. Johansen *et al*. (2007) [17] found that priming produced more B:C ratio. The benefit-cost ratio for the farmers using the improved varieties has been estimated to be around 2.18 in Bangladesh (Afzal *et al*. 2004) [2]. These findings are in a great analogy with the previous work of Binang *et al*. (2012) [7], who observed maximum net returns with seed priming in direct seeded rice. Anitha *et al*. (2013) [3] were of the opinion that maximum benefit obtained from seed priming could be due to full yield potential of soybean indicating that it is essential to go for seed treatment that enhance crop growth and seed yield by minimizing the pest and disease incidence rather than adopting only normal sowing (without seed treatment).

Table 1: Initial soil physico-chemical properties of experimental site (0-0.15 m depth)

S. No.	Soil property	Value
i.	Mechanical separates (%)	
	Sand	19.7
	Silt	62.6
	Clay	16.4
	Texture	Silty loam
ii.	Soil pH	6.1
iii.	Organic carbon (g kg^{-1})	6.3
iv.	CEC [c mol(p^{+}) kg^{-1}]	11.5
v.	Available Nutrients (kg ha^{-1})	
	Nitrogen	225.8
	Phosphorus	27.8
	Potassium	169.2
vi.	DTPA extractable micronutrients (mg kg^{-1})	
	Fe	7.23
	Mn	2.28
	Zn	1.27
	Cu	1.35

Table 2: Effect of priming levels and their duration on crop yields (q ha^{-1})

Treatments	2014-15 Pea	2015 Maize	Maize equivalent yield	2015-16 Pea	2016 Maize	Maize equivalent yield	Pooled pea yield (2014-15 &2015-16)	Pooled maize yield (2015 &2016)	Pooled maize equivalent yield
A. Priming Level									
0% Zn (water soaking)	116.2	41.5	220.2	119.1	42.8	226.0	117.7	42.1	223.1
1% $ZnSO_4$	123.5	48.0	238.0	126.6	49.5	244.2	125.1	48.7	241.1
2% $ZnSO_4$	107.9	53.8	219.7	110.6	55.6	225.7	109.2	54.7	222.7
3% $ZnSO_4$	66.3	32.2	134.1	68.7	32.9	138.6	67.5	32.6	136.4
LSD (P=0.05)	4.9	4.2	7.9	5.4	4.7	8.6	5.1	4.4	8.2
B. Priming Duration									
4 hours	94.1	36.8	181.6	96.9	38.1	187.1	95.5	37.4	184.3
8 hours	104.6	43.8	204.8	107.4	45.2	210.4	106.0	44.5	207.6
12 hours	111.7	51.0	222.7	114.4	52.3	228.4	113.0	51.7	225.6
LSD (P=0.05)	4.3	3.6	6.8	4.6	4.0	7.4	4.4	3.8	7.1
Interaction A × B	S	S	S	S	S	S	S	S	S
Soil application vs priming									
Soil application	89.5	36.0	173.7	92.1	37.5	179.2	90.8	36.7	176.4
Priming	103.5	43.9	203.0	106.2	45.2	208.6	104.8	44.5	205.8
LSD (P=0.05)	6.3	5.3	10.0	6.8	5.9	10.9	6.5	5.6	10.4
Control vs Others									
Control	85.7	34.2	166.1	88.2	35.7	171.4	87.0	35.0	168.8
Others	102.4	43.3	200.8	105.1	44.6	206.4	103.8	43.9	203.6
LSD (P=0.05)	6.3	5.3	10.0	6.8	5.9	10.9	6.5	5.6	10.4

Table 3: Effect of priming levels and their duration on stover yields (q ha^{-1})

Treatments	2014-15 Pea	2015 Maize	2015-16 Pea	2016 Maize	Pooled pea	Pooled maize
A. Priming Level						
0% Zn (water soaking)	27.7	53.2	29.1	54.9	28.4	54.0
1% $ZnSO_4$	30.9	62.3	32.5	64.3	31.7	63.3
2% $ZnSO_4$	24.5	71.0	25.7	73.6	25.1	72.3
3% $ZnSO_4$	14.1	37.7	14.9	38.8	14.5	38.3
LSD (P=0.05)	1.1	5.4	1.3	6.1	1.2	5.8
B. Priming Duration						
4 hours	22.1	45.9	23.3	47.7	22.7	46.8
8 hours	24.5	56.3	25.8	58.2	25.1	57.2
12 hours	26.2	65.9	27.5	67.8	26.9	66.8
LSD (P=0.05)	1.0	4.7	1.1	5.3	1.1	5.0
Interaction A × B	2.0	9.4	2.2	10.6	2.1	10.0
Soil application vs priming						
Soil application	19.9	45.6	20.9	47.5	20.4	46.6
Priming	24.3	56.0	25.5	57.9	24.9	57.0
LSD (P=0.05)	1.5	6.9	1.6	7.8	1.5	7.3
Control vs Others						
Control	19.3	43.1	20.4	45.0	19.9	44.1
Others	24.0	55.2	25.2	57.1	24.6	56.2
LSD (P=0.05)	1.5	6.9	1.6	7.8	1.5	7.3

Table 4: Effect of priming levels on net returns of pea and maize crop

Treatments	2014-15 Pea	2015 Maize	2015-16 Pea	2016 Maize	Pooled pea	Pooled maize
A. Priming Level						
0% Zn (water soaking)	175723	35501	181938	37796	178830	36648
1% $ZnSO_4$	191113	47009	197788	49679	194450	48344
2% $ZnSO_4$	157765	57515	163524	60740	160645	59128
3% $ZnSO_4$	71313	17611	76362	18935	73837	18273
LSD (P=0.05)	10181	7277	11109	8150	10620	7693
B. Priming Duration						
4 hours	129582	26720	135492	28962	132537	27841
8 hours	151396	39414	157321	41852	154358	40633
12 hours	165957	52092	171896	54548	168927	53320
LSD (P=0.05)	8817	6302	9620	7058	9197	6662
Interaction A × B	17635	12604	19241	14115	18395	13324
Soil application vs priming						
Soil application	118467	25212	123980	27837	121223	26525
Priming	148978	39409	154903	41787	151941	40598
LSD (P=0.05)	12979	9276	14161	10389	13538	9806
Control vs Others						
Control	118564	27600	123871	30217	121217	28909
Others	146631	38317	152524	40714	149578	39516
LSD (P=0.05)	12940	9249	14119	10358	13498	9777

Table 5: Effect of priming levels and their duration on benefit cost ratio (B:C) of pea and maize crop

Treatments	2014-15 Pea	2015 Maize	2015-16 Pea	2016 Maize	Pooled pea	Pooled maize
A. Priming Level						
0% Zn (water soaking)	2.70	0.96	2.80	1.02	2.75	0.99
1% $ZnSO_4$	2.93	1.27	3.04	1.34	2.98	1.30
2% $ZnSO_4$	2.42	1.54	2.50	1.63	2.46	1.59
3% $ZnSO_4$	1.09	0.47	1.17	0.51	1.13	0.49
LSD (P=0.05)	0.16	0.19	0.17	0.21	0.16	0.20
B. Priming Duration						
4 hours	1.99	0.72	2.08	0.78	2.03	0.75
8 hours	2.32	1.06	2.41	1.12	2.37	1.09
12 hours	2.55	1.40	2.64	1.47	2.59	1.43
LSD (P=0.05)	0.14	0.17	0.15	0.19	0.14	0.18
Interaction A × B	0.27	0.33	0.30	0.37	0.28	0.35
Soil application vs priming						
Soil application	1.78	0.67	1.86	0.74	1.82	0.71
Priming	2.29	1.06	2.38	1.12	2.33	1.09
LSD (P=0.05)	0.20	0.24	0.22	0.27	0.21	0.26
Control vs Others						
Control	2.02	0.74	2.11	0.80	2.07	0.77

Others	2.25	1.03	2.34	1.09	2.29	1.06
LSD (P=0.05)	0.20	0.24	0.22	0.27	0.21	0.26

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